Bureau International des Poids et Mesures

Consultative Committee for Photometry and Radiometry (CCPR)

16th Meeting (April 2001)

Note on the use of the English text

To make its work more widely accessible the International Committee for Weights and Measures publishes an English version of its reports.

Readers should note that the official record is always that of the French text. This must be used when an authoritative reference is required or when there is doubt about the interpretation of the text.

TABLE OF CONTENTS

MEMBER STATES OF THE METRE CONVENTION AND ASSOCIATES OF THE GENERAL CONFERENCE

as of 24 April 2001

Member States of the Metre Convention

Argentina
Australia
Austria
Belgium
Brazil
Bulgaria
Cameroon
Canada
Chile
China
Czech Republic
Denmark
Dominican Republic
Egypt
Finland
France
Germany
Greece
Hungary
India
Indonesia
Iran (Islamic Rep. of)
Ireland
Israel
Italy
Japan
Korea (Dem. People's Rep. of)
Korea (Rep. of)
Mexico
Netherlands
New Zealand
Norway
Pakistan
Poland
Portugal
Romania
Russian Federation
Singapore
Slovakia
South Africa
Spain
Sweden
Switzerland
Thailand
Turkey
United Kingdom
United States
Uruguay
Venezuela

Associates of the General Conference

Cuba
Ecuador
Hong Kong, China
Latvia
Lithuania
Malta

THE BIPM AND THE METRE CONVENTION

The International Bureau of Weights and Measures (BIPM) was set up by the Metre Convention signed in Paris on 20 May 1875 by seventeen States during the final session of the diplomatic Conference of the Metre. This Convention was amended in 1921.

The BIPM has its headquarters near Paris, in the grounds (43 520 m^2) of the Pavillon de Breteuil (Parc de Saint-Cloud) placed at its disposal by the French Government; its upkeep is financed jointly by the Member States of the Metre Convention.

The task of the BIPM is to ensure worldwide unification of physical measurements; its function is thus to:

- establish fundamental standards and scales for the measurement of the principal physical quantities and maintain the international prototypes;
- carry out comparisons of national and international standards;
- ensure the coordination of corresponding measurement techniques;
- carry out and coordinate measurements of the fundamental physical constants relevant to these activities.

The BIPM operates under the exclusive supervision of the International Committee for Weights and Measures (CIPM) which itself comes under the authority of the General Conference on Weights and Measures (CGPM) and reports to it on the work accomplished by the BIPM.

Delegates from all Member States of the Metre Convention attend the General Conference which, at present, meets every four years. The function of these meetings is to:

- discuss and initiate the arrangements required to ensure the propagation and improvement of the International System of Units (SI), which is the modern form of the metric system;
- confirm the results of new fundamental metrological determinations and various scientific resolutions of international scope;
- take all major decisions concerning the finance, organization and development of the BIPM.

The CIPM has eighteen members each from a different State: at present, it meets every year. The officers of this committee present an annual report on the administrative and financial position of the BIPM to the Governments of

the Member States of the Metre Convention. The principal task of the CIPM is to ensure worldwide uniformity in units of measurement. It does this by direct action or by submitting proposals to the CGPM.

The activities of the BIPM, which in the beginning were limited to measurements of length and mass, and to metrological studies in relation to these quantities, have been extended to standards of measurement of electricity (1927), photometry and radiometry (1937), ionizing radiation (1960), time scales (1988) and to chemistry (2000). To this end the original laboratories, built in 1876-1878, were enlarged in 1929; new buildings were constructed in 1963-1964 for the ionizing radiation laboratories, in 1984 for the laser work, and in 1988 for a library and offices. In 2001 a new building for the workshop, offices and meeting rooms was opened.

Some forty-five physicists and technicians work in the BIPM laboratories. They mainly conduct metrological research, international comparisons of realizations of units and calibrations of standards. An annual report, the *Director's Report on the Activity and Management of the International Bureau of Weights and Measures*, gives details of the work in progress.

Following the extension of the work entrusted to the BIPM in 1927, the CIPM has set up bodies, known as Consultative Committees, whose function is to provide it with information on matters that it refers to them for study and advice. These Consultative Committees, which may form temporary or permanent working groups to study special topics, are responsible for coordinating the international work carried out in their respective fields and for proposing recommendations to the CIPM concerning units.

The Consultative Committees have common regulations (*BIPM Proc.-Verb. Com. Int. Poids et Mesures*, 1963, **31**, 97). They meet at irregular intervals. The chairman of each Consultative Committee is designated by the CIPM and is normally a member of the CIPM. The members of the Consultative Committees are metrology laboratories and specialized institutes, agreed by the CIPM, which send delegates of their choice. In addition, there are individual members appointed by the CIPM, and a representative of the BIPM (Criteria for membership of Consultative Committees, *BIPM Proc.-Verb. Com. Int. Poids et Mesures*, 1996, **64**, 124). At present, there are ten such committees:

1 the Consultative Committee for Electricity and Magnetism (CCEM), new name given in 1997 to the Consultative Committee for Electricity (CCE) set up in 1927;

2 the Consultative Committee for Photometry and Radiometry (CCPR), new name given in 1971 to the Consultative Committee for Photometry (CCP) set up in 1933 (between 1930 and 1933 the CCE dealt with matters concerning photometry);

3 the Consultative Committee for Thermometry (CCT), set up in 1937;

4 the Consultative Committee for Length (CCL), new name given in 1997 to the Consultative Committee for the Definition of the Metre (CCDM), set up in 1952;

5 the Consultative Committee for Time and Frequency (CCTF), new name given in 1997 to the Consultative Committee for the Definition of the Second (CCDS) set up in 1956;

6 the Consultative Committee for Ionizing Radiation (CCRI), new name given in 1997 to the Consultative Committee for Standards of Ionizing Radiation (CCEMRI) set up in 1958 (in 1969 this committee established four sections: Section I (X- and γ-rays, electrons), Section II (Measurement of radionuclides), Section III (Neutron measurements), Section IV (α-energy standards); in 1975 this last section was dissolved and Section II was made responsible for its field of activity);

7 the Consultative Committee for Units (CCU), set up in 1964 (this committee replaced the "Commission for the System of Units" set up by the CIPM in 1954);

8 the Consultative Committee for Mass and Related Quantities (CCM), set up in 1980;

9 the Consultative Committee for Amount of Substance (CCQM), set up in 1993;

10 the Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV), set up in 1998.

The proceedings of the General Conference, the CIPM and the Consultative Committees are published by the BIPM in the following series:

- *Reports of the meetings of the General Conference on Weights and Measures;*
- *Reports of the meetings of the International Committee for Weights and Measures;*
- *Reports of the meetings of Consultative Committees.*

The BIPM also publishes monographs on special metrological subjects and, under the title *The International System of Units (SI)*, a brochure, periodically updated, in which are collected all the decisions and recommendations concerning units.

The collection of the *Travaux et Mémoires du Bureau International des Poids et Mesures* (22 volumes published between 1881 and 1966) and the *Recueil de Travaux du Bureau International des Poids et Mesures* (11 volumes published between 1966 and 1988) ceased by a decision of the CIPM.

The scientific work of the BIPM is published in the open scientific literature and an annual list of publications appears in the *Director's Report on the Activity and Management of the International Bureau of Weights and Measures*.

Since 1965 *Metrologia*, an international journal published under the auspices of the CIPM, has printed articles dealing with scientific metrology, improvements in methods of measurement, work on standards and units, as well as reports concerning the activities, decisions and recommendations of the various bodies created under the Metre Convention.

LIST OF MEMBERS OF THE CONSULTATIVE COMMITTEE FOR PHOTOMETRY AND RADIOMETRY

as of 24 April 2001

President

A.J. Wallard, member of the International Committee for Weights and Measures, National Physical Laboratory, Teddington.

Executive secretary

R. Köhler, International Bureau of Weights and Measures [BIPM], Sèvres.

Members

Bureau National de Métrologie, Institut National de Métrologie [BNM-INM], Paris.

CSIR, National Metrology Laboratory [CSIR-NML], Pretoria.

Helsinki University of Technology [HUT], Espoo.

Institute for Opto-Physical Measurements, Gosstandart of Russia [VNIIOFI], Moscow.

Instituto de Física Aplicada, Consejo Superior de Investigaciones Cientificas [IFA-CSIC], Madrid.

Istituto Elettrotecnico Nazionale Galileo Ferraris [IEN], Turin.

Korea Research Institute of Standards and Science [KRISS], Daejeon.

Measurement Standards Laboratory of New Zealand [MSL], Lower Hutt.

National Institute of Metrology [NIM], Beijing.

National Institute of Standards and Technology [NIST], Gaithersburg.

National Measurement Laboratory, CSIRO [NML-CSIRO], Lindfield.

National Metrology Institute of Japan, National Institute of Advanced Industrial Science and Technology [NMIJ/AIST], Tsukuba.

National Office of Measures/Országos Mérésügyi Hivatal [OMH], Budapest.

National Physical Laboratory [NPL], Teddington.

National Research Council of Canada [NRC], Ottawa.

NMi Van Swinden Laboratorium, Nederlands Meetinstituut [NMi VSL], Delft.

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig.

Slovak Institute of Metrology/Slovenský Metrologický Ústav [SMU], Bratislava.

Swiss Federal Office of Metrology and Accreditation [METAS], Wabern.

The Director of the International Bureau of Weights and Measures [BIPM], Sèvres.

Observers

Centro Nacional de Metrología [CENAM], Queretaro.

National Metrology Institute/Ulusal Metroloji Enstitüsü [UME], Gebze-Kocaeli.

Singapore Productivity and Standards Board [PSB], Singapore.

Consultative Committee
for Photometry and Radiometry

Report of the 16th meeting

(24-26 April 2001)

to the International Committee for Weights and Measures

Agenda

1 Opening of the meeting; agenda; appointment of a rapporteur.
2 Review of progress in the laboratories.
3 Discussion of the status and results of key comparisons:
  3.1 Spectral irradiance CCPR-K1;
  3.2 Spectral responsivity CCPR-K2;
  3.3 Spectral diffuse reflectance CCPR-K5;
  3.4 Spectral regular transmittance CCPR-K6;
  3.5 Discussion.
4 Status and results of supplementary comparisons:
  4.1 Spectral radiance CCPR-S1;
  4.2 Aperture area CCPR-S2;
  4.3 Cryogenic radiometers CCPR-S3.
5 Status and results of RMO comparisons:
  5.1 APMP;
  5.2 SIM;
  5.3 EUROMET;
  5.4 SADCMET.
6 Other comparison matters.
7 Status of the BIPM key comparison database.
8 Report from the Working Group on Key Comparisons:
  8.1 Regional comparisons;
  8.2 CMC data;
  8.3 Future review of CMC claims;
  8.4 Key comparison common processing system;
  8.5 Processing of spectral data.
9 Vocabulary for CMC entries in radiometry and photometry.
10 Report from the Working Group on Air-UV Spectral Radiometry.
11 Future work programme of the CCPR.
12 Future work programme of the BIPM.

13 Recommendation to the CIPM.

14 Liaison to CCT Working Group 5 on Radiation Thermometry.

15 Liaison to other organizations:

15.1 CIE;

15.2 CORM.

16 Other business: NEWRAD.

17 Next meeting.

1 OPENING OF THE MEETING; AGENDA; APPOINTMENT OF A RAPPORTEUR

The Consultative Committee for Photometry and Radiometry (CCPR) held its 16th meeting at the International Bureau of Weights and Measures (BIPM), Sèvres, on Tuesday 24 April through Thursday 26 April 2001. Five sessions were held.

The following were present: J. Bastie (BNM-INM), A. Bittar (MSL), P. Blattner (METAS), L.P. Boivin (NRC), A. Corróns (IFA-CSIC), G. Day (NIST), G. Dézsi (OMH), N.P. Fox (NPL), J.L. Gardner (NML-CSIRO), E. van der Ham (NMi VSL), E. Ikonen (HUT), C. Johnson (NIST), In Won Lee (KRISS), Lin Yandong (NIM), J. Metzdorf (PTB), P. Nemeček (SMU), D. Nettleton (NPL), T.J. Quinn (Director of the BIPM), M.L. Rastello (IEN), T. Saito (NMIJ), V. Sapritsky (VNIIOFI), W. Schmutz (PMOD/WRC, expert of METAS), B. Theron (CSIR-NML), A.J. Wallard (President of the CCPR), B. Wende (PTB), J. Zwinkels (NRC).

Observers: C. Matamoros (CENAM), K. Türkoglu (UME), Xu Gan (PSB).

Also attending the meeting: P. Giacomo (Director emeritus of the BIPM), R. Goebel, R. Köhler, S. Solve, M. Stock, C. Thomas (BIPM).

The President opened the meeting, welcoming representatives and observers. A letter of thanks to Prof. Soardo, recently retired as a long-standing representative, was circulated for signatures.

Dr Gardner was appointed as rapporteur.

The agenda was adopted.

The working documents were listed in Appendix P 1.

The President invited the BIPM Director to address the meeting. Dr Quinn welcomed all to the BIPM for this last CCPR meeting in the old building. The increasing importance of international metrology was evidenced by the fact that he was expected the next day at a meeting on a draft ISO/IEC standard which would impact on the national metrology institutes and the operation of their accreditation systems. He noted that, following the introduction of the Mutual Recognition Arrangement (MRA), the CIPM was updating its report on the future needs of international metrology and welcomed any comments during the meeting related to needs in photometry

and radiometry. Dr Quinn especially welcomed Dr Schmutz, Director of the World Radiation Center (WRC), noting that the 21st CGPM had previously passed Resolution 4 (1999) encouraging the use of SI units for environmental measurement. He also expressed the intent for future BIPM meetings to be paperless as far as possible, with committee documents to be available on a dedicated website.

2 REVIEW OF PROGRESS IN THE LABORATORIES

Dr Wallard said that one goal of the questionnaire on progress and future work (CCPR/01-07) was that laboratories may actively seek cooperation to share knowledge and resources in undertaking new work. Most laboratories had submitted written reports and he invited members to speak to those.

Dr Blattner noted a change in name of the Swiss laboratory, now METAS, and that fibre-optic measurements were important. The laboratory would welcome comparisons of optical fibre power meters and of chromatic dispersion.

Mr Theron indicated that the CSIR now trace to a cryogenic radiometer, but had plans to improve their room-temperature radiometer. A new reference spectrophotometer was available. The laboratory saw the need for traceable measurements of gloss and refractive index, and for lasers used in medical areas.

Dr Lin reported that the NIM has improved standards for colour temperature, based on a black body, was developing diffuse reflectance standards based on a diffuse zero-degree geometry, and was cooperating on the development of UV standards based on synchrotron radiation. Measurement of LEDs was increasingly important.

Prof. Corróns said that the IFA-CSIC has developed new standards for spectral responsivity in the 200 nm – 400 nm range based on silicon trap detectors and the cryogenic radiometer. A new goniophotometer had been constructed for luminous flux measurements.

Prof. Ikonen reported that the HUT has devoted much effort to the calibration of UV radiometers and improvement of UV measurement accuracy with filter radiometers. He noted the importance of accurate

wavelength calibration (errors up to 0.5 nm have been seen) and that filter stability has been disappointing. In reply to Prof. Wende's question on agreement of the silicon quantum yield at UV wavelengths with previous measurements, he said that the HUT and the PTB were currently comparing results.

Dr Lee mentioned that the KRISS is progressing with the development of spectral irradiance scales based on a high-temperature black body.

Prof. Sapritsky noted that the VNIIOFI has developed promising new black-body sources based on the eutectic materials, iridium and rhenium carbides. They had been collaborating with temperature experts at the NMIJ/AIST (former NRLM) to determine the stability and reproducibility of the melting and freezing points of these materials; results would be presented at TempMeko in June 2001.

Prof. Metzdorf reported that within the PTB responsibility for spectral responsivity standards had moved to Berlin. LED photometry has become increasingly important. The laboratory was progressing with development of a complex robot for goniophotometry. He noted that the CCPR had broadened its interest from the traditional areas and suggested that future questionnaires should have specific entries for fibre optics and material measurements. Prof. Wende pointed out that spectral responsivity measurements at PTB Berlin are now based on cryogenic electrical substitution radiometers as primary detector standards in the full spectral range from the NIR to the hard X-ray region, i.e. for photon energies from 0.7 eV to 10 keV. Monochromatic synchrotron radiation is used at photon energies above 3 eV, and laser radiation below 5.4 eV. In order to extend cryogenic radiometry further into the IR up to 10 µm, a new measuring facility allows the use of an arc plasma with high power density (25 kW/cm^3) as an IR radiation source. With this source, monochromatic radiation fluxes are obtained which are an order of magnitude higher than those of conventional IR sources. The PTB Berlin has also developed extensive instrumentation in order to support the semiconductor industry in the field of photolithography below 200 nm, in particular for 157 nm and 13 nm radiation. For 13 nm, the typical relative uncertainty of reflectance measurements of Mo-Si multilayers to be used for projecting mask structures onto wafers is 0.2 %.

Dr Zwinkels reported that the NRC has completed the development of sphere-based radiometers as near-IR transfer standards for spectral responsivity. A copper-point black body has been applied to improve the NRC spectral radiance scales. Spectrophotometric measurements had been

improved by upgrading the reference instrument and FT-IR techniques had been used with better detectors for more accurate measurements in the range 2 μm – 25 μm. Dr Boivin saw the need for the CCPR to be more active in this region to provide support for Appendix C uncertainty claims.

In his report Dr Gardner mentioned that the CSIRO had developed improved understanding of uncertainties for properties such as colour, which may not be compared directly but could be related to uncertainties in spectral scales. New calculations were shown on correlation which may be present in primary spectral scales.

Dr Johnson gave a presentation on extensive developments in radiometry at the NIST. Applications for low background infra-red calibrations, and for space-based measurement were highlighted; special problems of alignment had been found in transferring calibrations to large instruments. The SIRCUS laser-based facility had been applied to the calibration of CCD cameras, and was to be used for photometer response calibrations. In the near future spectral irradiance calibrations would be traced directly to the cryogenic radiometer through filter radiometry setting the temperature of a reference black body, with uncertainties expected to be 3-4 times lower than previous determinations. The synchrotron facilities at the NIST had been recently upgraded to achieve an uncertainty of 0.5 % for spectral responsivity in the 125 nm – 320 nm wavelength range. Dr Day presented the perspective from the NIST Boulder laboratories. A need was seen for the calibration of excimer lasers at 157 nm and 190 nm, and the NIST welcomed collaboration with other laboratories in this area. Main calibration activities related to high-power lasers (up to 10 kW) and to fibre-optic communications. A domain-engineered pyroelectric detector had been developed for 0.1 % accuracy in the near-IR range. Detector frequency response could now be determined to 50 GHz, with the need foreseen to be able to extend this to 110 GHz. Mr Nettleton asked about developments at the NIST in appearance-related measurements; he was referred to Dr Nadal of the NIST for details. Dr Johnson announced that Bob Saunders, who was a co-delegate for the NIST at several CCPR meetings, was retiring. A letter of thanks for signature by the attendees was circulated.

Dr Fox reported on progress with the absolute radiation detector at the NPL. The discrepancy in measurement of the order of 0.1 % was now thought to be related to the black coating of the radiator having high reflectance at grazing angles, a problem that should be overcome by returning to the use of Nextel black paint. A monochromator-coupled cryogenic radiometer system was being developed, with a noise floor of 10 pW. Laser-based radiometry

was now available over a wide, tuneable wavelength range. The NPL was developing a filter radiometer with imaging optics to measure thermodynamic temperatures of freezing points. Discrepancies of the order of 0.5 % in sphere-based and goniometer-based reflectance values were being studied. New glasses of high stability had been developed for filter radiometers at UV wavelengths. Dr Boivin queried the need for these as the high-temperature black bodies could be adequately characterized at visible wavelengths. Dr Fox replied that UV measurements were required to verify the cavity emissivity at UV wavelengths. Prof. Wende agreed, noting that the high-temperature cavities were generally not isothermal and so their emission needed to be characterized at UV wavelengths. Dr Fox also reported on advances in Fourier transform spectrometry and on the move to new facilities at the NPL.

Mr Bastie reported that the BNM had developed filter radiometers with GaAsP photodiodes 10 mm square for realizing spectral irradiance scales in the 200 nm – 400 nm range. Other developments had involved changes to the optical system for spectral responsivity measurements to enable the cavity pyroelectric reference detector to be compared with trap detectors. In reply to Dr Boivin's questions on the uniformity of response of the GaAsP detectors, Mr Bastie stated that the better ones varied by about 1 % over the central area, but degrading to 10 % – 15 % at the perimeter. The uniformity is, however, improved in a trap configuration.

Dr Bittar reported that the MSL had continued its use of five-element trap detectors for reference standards to characterize filter radiometers. The laboratory had recently re-realized its candela, traced now to a cryogenic radiometer with a shift in value of 0.96 %. Current work was concentrated on UV spectral irradiance scales and it was noted that the 18 mm square Hamamatsu detectors were not as specular as the smaller S1337 types. Dr Gardner said that the CSIRO had reduced the diffuse component of reflection of aged large types by cleaning and so restored agreement in orthogonal measurements with the four-element transmission traps. Dr Bittar noted that the surface quality of the large-area detectors did not appear as good to the eye.

Dr Saito said that the ETL was now part of a wider institute to be known as the NMIJ, the National Metrology Institute of Japan. He reported results showing the importance of characterizing beam divergence when comparing the response of silicon detectors especially at wavelengths in the 10 nm – 200 nm range regardless of incident beam polarization. In response to Prof. Wende's question, he reported that the He^3 cryogenic radiometer is

being constructed in the laboratory but based on a commercially available cryostat.

Dr Dézsi reported that he had not received the CCPR questionnaire. The OMH is concentrating on comparison measurements, and developing imaging radiometers using Ge and InGaAs detectors for temperature measurement. He did not take part in CCPR-K6 due to problems with his instrument but he participates in a EUROMET comparison of regular transmittance measurements.

Dr van der Ham remarked that the NMi VSL now calibrates the response of filter radiometers directly against a monochromator-based cryogenic radiometer. Dr Boivin asked whether the significant differences seen in a bilateral comparison with the PTB on the response of Pt-Si detectors had been resolved. Dr van der Ham replied that agreement had been reached; the problems were with the scales, not the detectors. Dr Fox said that the differences were due to errors in wavelength. The NMi VSL is developing a new facility for spectral irradiance which will be completed in two years.

Dr Nemeček said that the main interest for the SMU is the calibration of the spectral responsivity of pyrometers, and devices such as attenuators and optical time-domain reflectometers used in communications. The laboratory was currently seeking accreditation for its calibration services.

Dr Rastello apologized for the lack of a written report. The laboratory was collaborating with the NIST and other EUROMET laboratories on correlated photon techniques for calibration at low light levels. The IEN is also collaborating with the NPL on an improved Si detector. A recent laboratory programme had been one for the safeguard of Italian cultural items involving measurement of the frescos and other relics.

Dr Xu pointed out that the PSB was establishing spectral responsivity scales traced to a cryogenic radiometer. Near-UV radiometry with broad-band detectors remained a priority. The laboratory has developed new facilities for the calibration of spectral irradiance lamps and spectral transmittance measurements. The latter will be used for their participation in CCPR-K6.

Mr Türkoglu reported that the UME now has a working cryogenic radiometer and a spectral responsivity scale in the visible based on a trap detector. They were currently comparing luminous intensity and flux values with the PTB. Areas seen as important were calibration of optical time-domain reflectometers, and retro-reflectance.

Mr Matamoros said that the CENAM had an operational cryogenic radiometer. Stability problems were experienced in the recent comparison

with the PTB. The laboratory is developing a luminous flux scale based on the absolute integrating sphere technique of Y. Ohno and the capability to calibrate UV radiometers.

Dr Schmutz noted that the World Meteorological Organization (WMO) maintains the world radiometric reference but had no official links to the SI at present, although such a link is planned. His attendance at the CCPR meeting is to establish an administrative link between the WMO and the CCPR. The Physikalisch-Meteorologisches Observatorium Davos, World Radiation Center (PMOD/WRC) maintains and operates for the WMO the primary standard for pyrheliometers at the solar power levels. Recently, the WMO had been asked to set up facilities to calibrate pyrgeometers and broad-band UV radiometers at the solar power levels and he saw the need for collaboration to do this.

Dr Köhler was asked to present developments at the BIPM. He deferred details to a later agenda item, but noted that responses to the questionnaire were difficult to summarize. Common views were expressed over concerns about the efforts involved in key comparisons, and a rising level of interest in UV calibrations. Calibrations in spectrophotometry and related to fibre optics were also common themes. There is a desire for improved lamps, transfer detectors and to a lesser extent improved IR measurements. No laboratory expressed interest in improving the state of the art of photometry, despite evidence from comparisons that agreement between laboratories had shown little improvement.

Following a general discussion about proposals for new working groups in the fields of IR, fibre optics, advanced technology and UV, Dr Wallard encouraged the members to reflect on these issues.

3 DISCUSSION OF THE STATUS AND RESULTS OF KEY COMPARISONS

3.1 Spectral irradiance CCPR-K1

3.1.1 CCPR-K1.a, 250 nm – 2500 nm

Dr Fox presented the written report CCPR/01-13. Of the thirteen laboratories participating in addition to the NPL as the pilot laboratory, four to date had

made measurements. The comparison had been delayed owing to the water quality problems with the high-temperature black body, which is the reference device, and may now be affected by the planned move of the laboratory to new premises in August-September 2001. If necessary, the NPL will add an extra measurement phase if measurements made after the move are required and if these indicate a systematic difference relative to the current facility. In response to Dr Johnson, he said that any such difference will be calibrated and all measurements would be corrected to the existing NPL scales. A draft A report was expected to be available around March 2002.

3.1.2 CCPR-K1.b, 200 nm – 400 nm

Prof. Metzdorf indicated that questionnaires on participation had been circulated and responses were due 31 May 2001. Overlap with the 250 nm – 2500 nm comparison was seen as an advantage as the deuterium spectrum contained lines at wavelengths above 360 nm. He said that a paper would be presented on the lamp selection process at the NEWRAD conference. It had not been possible to develop detector-stabilized lamps. He suggested that a silicon carbide detector could be used to monitor long-term drift, being placed in the beam path before and after a series of measurements. He questioned whether the spectral range 190 nm – 360 nm might be more appropriate to avoid the line problem and to extend measurements to slightly shorter wavelengths. Dr Johnson preferred the 200 nm – 400 nm range be retained, as this was the NIST service range. Mr Nettleton was cautious about moving below 200 nm and preferred to retain the upper limit of 400 nm; only one point in the range may be susceptible to the line emission and problems could be reduced by specifying the measurement bandwidth. Dr Zwinkels asked whether it would be possible to participate in a limited range. Prof. Metzdorf replied that the upper end already overlapped the tungsten-based comparison and was wary of the increased workload. Dr Köhler said that the timescales for the two spectral ranges already overlapped.

Dr Wallard summarized the discussion, noting agreement to retain the 200 nm – 400 nm range; participation in a restricted range may be considered once all the responses are known. Five laboratories had previously indicated interest to the PTB; of these, only one expressed interest at the meeting in measuring an FEL lamp as well as the deuterium lamps in this comparison. Mr Nettleton suggested that the usefulness of such an inclusion may depend

on the success of detector stabilization; the NPL had some experience in this area and could collaborate with the PTB.

3.2 Spectral responsivity CCPR-K2

3.2.1 CCPR-K2.a, 900 nm – 1600 nm

Dr Johnson reported that all four measurement rounds were completed, and that the photodiodes appeared to have been stable. The data were being reduced and a draft A report should be available in October 2001. In response to a question from Prof. Ikonen, Mr Nettleton reminded the committee of the previous decision to use a weighted mean at each wavelength to calculate the reference values.

3.2.2 CCPR-K2.b, 300 nm – 1000 nm

Mr Goebel reported satisfactory progress. Transfer detectors were distributed in the first round in September 2000 and were received back in February 2001. One laboratory has postponed its participation due to failure of its spectral responsivity facility. The second round of detectors was due back, with a further nine laboratories to participate.

3.2.3 CCPR-K2.c, 200 nm – 400 nm

Prof. Wende presented overheads from Dr Rabus, the coordinator. The Hamamatsu S5227 photodiodes had all been obtained, with each participant to receive one trap detector and three individual detectors. However, only twenty-two of the required one hundred and forty Pt-Si photodiodes had been received to date, owing to a processing failure at the ETH. The protocol for the comparison had been agreed by the Working Group on Key Comparisons (WGKC) but not yet distributed because of the uncertain timescale for delivery of the remaining detectors. It was hoped that the comparison could begin in March 2002 and be completed February 2003. Prof. Wende said that there was no alternative choice for the Pt-Si detectors which had comparable stability. Dr Boivin asked whether the BNM had determined the stability of the GaAsP photodetectors in the UV. Mr Bastie replied that 0.2 % could be achieved, after ageing. Prof. Wende reminded the committee of the extensive experience with the Pt-Si detectors, and that they remained the detector of choice for the shorter wavelengths in particular.

3.3 Spectral diffuse reflectance CCPR-K5

Prof. Metzdorf reported that the protocol was still under discussion, as it is difficult to determine suitable artefacts. Choices were Spectralon, opal glass or tiles. Bilateral comparisons among the NIST, the NRC and the PTB had shown reasonable agreement with Spectralon 99. Dr Zwinkels said that the NRC had achieved good results with Russian opal glass, showing both high uniformity and negligible photoluminescence, provided the glass was professionally polished before first use. The PTB measurements on Spectralon 99 had been unstable at short wavelengths. Prof. Metzdorf agreed, quoting degradation of up to 15 % at 400 nm. Even samples kept in the dark for nine months showed a 5 % change. Dr Johnson said cleanliness of Spectralon was known to create problems with UV measurements. The revised start date for this comparison is October 2001. Dr Bittar asked if it was still possible to join this comparison.

3.4 Spectral regular transmittance CCPR-K6

Mr Bastie reported that fifteen of the eighteen filter sets had been returned as of December 2000. The BNM were completing the return measurements and a draft A report was expected to be completed by October 2001. He noted that this comparison included participants who were observers but not members of the CCPR.

3.5 Discussion

Dr Wallard noted that the CCPR had previously decided that only CCPR members could be included in the derivation of a key comparison reference value. Dr Quinn suggested that all participants who are technical experts could contribute, provided their participation is arranged prior to the start of the comparison. Mr Nettleton noted this difference in relation to the previous decision, where two observer laboratories had joined the luminous intensity comparison after it commenced. The committee agreed that Section 5 of the MRA Guidelines for the CIPM key comparisons was sufficiently clear; the working group decides who will participate before the comparison begins, and all contribute to the data reduction whether members or observers of the CCPR.

On the late participation in the spectral diffuse reflectance comparison, it was decided that the MSL could request participation as the protocol is still being determined. The NIM noted a similar interest; Dr Bittar and Dr Lin were requested to contact the convenor, Dr Early of the NIST, directly.

The question of the publication of results was raised. Dr Köhler reminded all that draft A results may be made known to other than the participants provided all participants agree and no laboratory is identifiable by name.

Dr Wallard thanked all for their efforts in these comparisons, particularly the convenors and pilot laboratories.

4 STATUS AND RESULTS OF SUPPLEMENTARY COMPARISONS

4.1 Spectral radiance CCPR-S1

Prof. Sapritsky reported that measurements were in progress, with a draft A report expected in July 2001. The NPL may have to delay measurements owing to the move to the new laboratory; if so, Prof. Sapritsky would prefer to delay the report rather than have the NPL withdraw and undertake a subsequent bilateral comparison.

4.2 Aperture area CCPR-S2

Dr Johnson said that both diamond-turned and machined artefacts were being circulated, with two more laboratories to participate. Measurements at the NRC had been delayed. Not all laboratories who had measured the artefacts had submitted their results. Some damage to the apertures had been observed.

4.3 Cryogenic radiometers CCPR-S3

Dr Köhler noted that the ETL (now NMIJ) and the IEN were undertaking a new round of measurements. Dr Gardner mentioned that two of the APMP laboratories, the NIM and the PSB, had expressed interest in repeating this regional comparison, but that it may be best for both to interact directly with the BIPM. This was agreed.

5 STATUS AND RESULTS OF RMO COMPARISONS

5.1 APMP

Dr Gardner reported that the APMP had completed a regional repeat of the CCPR-K3.b key comparison of luminous responsivity, piloted by the CSIRO. Two laboratories, the CSIRO and the MSL participated at both the consultative committee level and the regional level, and their results in the two comparisons were consistent, once a recent change in the MSL realization of the candela had been taken into account. The remaining participants were thus able to be reliably linked to the key comparison reference value. The BIPM had made an alternative calculation of the degrees of equivalence and agreed with the results in the report. The WGKC had received the report and approved its publication in Appendix B of the MRA as APMP.PR-K3.b provided the NPL (India) was re-identified as the NPLI and the MSL provided information on their uncertainty claim to the WGKC.

Dr Gardner stated that no other regional comparisons were planned. The few APMP laboratories that required links to key comparison reference values would be most efficiently handled by bilateral comparisons, as the bulk of the APMP laboratories interested in radiometry rather than basic photometry were members of the CCPR.

5.2 SIM

Mr Matamoros said that the SIM had undertaken a comparison of spectral transmittance and asked whether this could be linked to CCPR-K6. Dr Zwinkels noted that the calibration used routine artefacts and a different protocol, but was performed in a totally blind manner. Dr Wallard said that the SIM should produce a report for the WGKC and ask that a link be produced if deemed possible by the WGKC.

5.3 EUROMET

Prof. Ikonen showed a list of EUROMET activities with regional repeats of the CCPR comparisons -K1.a, -K2.a, -K2.b, -K3.a, -K4, -K5 and -K6, some with up to eight CCPR laboratories participating and able to contribute links to the key comparison reference values. Some discussion arose as to correct nomenclature to be used for the K2.a repeats, which were organized as two

bilateral comparisons. They are now named EUROMET.PR-BK2.a1 and EUROMET.PR-BK2.a2.

5.4 SADCMET

Mr Theron reported that within SADCMET only South Africa was active in photometry and radiometry.

6 OTHER COMPARISON MATTERS

The President noted the document from Dr Parr (CCPR/01-4) suggesting the continued monitoring of the need for comparisons in non-traditional CCPR areas. The committee agreed with the suggestion that the WGKC should include this role in their activities.

Dr Fox asked for the correct classification of two bilateral comparisons in spectral transmittance undertaken by the NPL. These were within the CCPR but across regions and outside the wavelength range of the CCPR key comparison. The comparison protocols had been notified to the CCPR secretary prior to beginning measurements. General discussion followed. It was decided that to be classed as a CCPR comparison all members of the CCPR must be invited. Comparisons of the type described were seen as pilots testing technology in newer areas, and would not be logged in Appendix B. When referring to the comparison to support Appendix C claims, reference to using full protocols of CCPR comparisons could be included in the comments field. The CCPR encouraged the practice of notifying the proposal and protocols of these comparisons to the secretary prior to their commencement. Dr Boivin registered concern that this practice should not be made mandatory and that results of published comparisons should continue to be recognized as a technical basis for supporting Appendix C submissions.

7 STATUS OF THE BIPM KEY COMPARISON DATABASE

Dr Thomas demonstrated the BIPM key comparison database to the participants, covering Appendix B and C entries and the search facilities. The ability to include links to laboratory websites was noted. Dr Thomas asked the laboratories to inform her directly of any mistyping in Appendix C material or updates on information. Any changes to the listed capabilities themselves required the full approval process of the Joint Committee of the Regional Metrology Organizations and the BIPM (JCRB). Dr Zwinkels asked why only material from EUROMET and the APMP appeared in Appendix C. Dr Thomas replied that only these regions had completed reviews in time for the March meeting of the JCRB for final approval, and in fact the material had been made available on the website only in the week prior to the CCPR meeting. Dr Thomas also demonstrated the equivalence matrix for key comparisons and showed how results from subsequent regional and bilateral comparisons would be added to the matrix.

8 REPORT FROM THE WORKING GROUP ON KEY COMPARISONS

Dr Wallard said that the group had met on the day preceding the CCPR and had a number of items to submit to the meeting for approval or discussion. Those items not covered elsewhere in the minutes are reported below.

8.1 Regional comparisons

The APMP.PR-K3.b comparison was the first to be fully linked to a CCPR comparison. It was noted that some participants were not signatories to the MRA, either as member States of the Metre Convention or associates of the CGPM. Since these participants may sign at a later date, the WGKC had reviewed the report including their results, but only the results for signatories to the MRA would be processed through to degrees of equivalence. The full report would appear, however, in Appendix B. The CCPR agreed with this procedure.

8.2 CMC data

For the first version of the Appendix C database, clarification of a range of uncertainties (as a function of measurand, wavelength, etc.) had been inserted as comments. Taking into account the importance of this information, it was recommended that such comments be included directly with the entry for the uncertainty range. Dr Thomas agreed to make this change for the existing data; laboratories needed to note this requirement for future entries.

A general discussion on the exactness of uncertainty specifications followed, particularly where a band of uncertainties was specified over a range of wavelengths. It was pointed out that uncertainties for the spectral irradiance of a deuterium lamp over the range 200 nm – 400 nm varied greatly. They cannot be specified as linear due to the problems of line emission at 370 nm. Dr Gardner observed that exact specification of uncertainties for spectral data would require an entry for each wavelength and that this was impractical; exceptions within the data such as that described at 370 nm could be identified in the comments column. Dr Boivin suggested that minimum and maximum uncertainties be specified for the range, but Dr Köhler remarked that the structure of the calibration and measurement capability (CMC) tables implies a linear variation of the uncertainty with wavelength if a range is specified. Mr Nettleton said that Appendix C should not be treated as a scientific document but as a guide for industry and regulators.

Consensus was that the spectral data (or other data where a range of uncertainty applies) should be split into relatively few ranges where the uncertainty can be treated as varying approximately linearly. Exceptions within the range could be noted in the comments column, where laboratories were also encouraged to include links to greater detail listed on their own websites.

8.3 Future review of CMC claims

The WGKC had asked the BIPM to maintain copies of the complete CMC data files, including comments columns used for review but not included in the public listing, with restricted access. Dr Gardner suggested that this idea could be extended further, in that the review process itself would be easier if the claim files were maintained on the BIPM server. This could be structured so that the laboratory alone had write access to its file, with read access made available first to the review team within a region, then to cross-regional teams and finally to the JCRB. This would avoid the problem of multiple

files circulating, often with the same name. Dr Thomas agreed this would be a useful system and would consider its introduction.

8.4 Key comparison common processing system

Dr Wallard reported on a new initiative by the BIPM to produce software for the processing of key comparison results. Developed by a small group of mathematicians and statisticians selected from a metrological environment, the outcome was expected to be fully checked software which would allow a pilot laboratory to enter information on results, uncertainties and known correlations, offer options on the type of mean required and process the result. The group dealing with this problem would also be asked to consider the problem of processing spectral data from the CCPR. The President noted concerns on the processing of key comparison results expressed by Dr Parr in a note to the WGKC. In response to questions, Dr Köhler said that the software was intended to be used by the pilot laboratory, where decisions will need to be made on methods to be used, and problems within a comparison identified; the software is intended to allow the choices but then process the result in a fully tested and described manner, avoiding rounding errors and other problems that have appeared in the past. The robustness of the software will be tested with existing comparison data. Dr Thomas agreed that the software will not do the science, and one key output would be a traceable record maintained by the BIPM of methods used, also decisions made when and by whom in the processing of comparison results. The software analysis method should be included as part of the technical protocol of a comparison.

8.5 Processing of spectral data

Mr Nettleton reminded members of the WGKC decision that until other advice becomes available, pilot laboratories should treat spectral data separately, extracting a key comparison reference value and uncertainty at each wavelength used in the comparison.

9 VOCABULARY FOR CMC ENTRIES IN RADIOMETRY AND PHOTOMETRY

Dr Gardner stated that problems had been encountered in entering CMC claims against the list agreed by the CCPR WGKC in June 2000. These mostly related to claims on artefacts of a general nature, where uncertainties could not be reliably specified in advance. This had led to a decision at the EUROMET meeting in January 2001, attended by all RMO representatives, to use a restricted list for the March 2001 round of claims and for Dr Goodman of the NPL and Dr Gardner of the CSIRO to suggest changes to the list of items. A document had been drafted clarifying the intent of CMC claims and proposing items to be deleted from the list, or deferred for further discussion (CCPR/01-15). These items had been approved by the WGKC at its meeting immediately preceding the CCPR meeting. It was agreed that those laboratories which had not been able to provide information for the March 2001 restricted list should have claims on these items rapidly processed for the October 2001 JCRB meeting, and that all other items not flagged for deletion would be processed within and across regions according to the JCRB timetable for its March 2002 meeting. Items flagged for deletion, or new items, would be considered for future JCRB cycles, but only after discussion and approval by the WGKC.

Dr Zwinkels expressed concern that the SIM region appeared to have missed out on the first round, as a result of internal communication delays. Dr Ikonen said that this was recognized by the JCRB, who had given advance approval for the first-round items provided agreement was reached among the regions. Dr Zwinkels also expressed frustration at the number of changes that had been required as instructions changed. Dr Johnson noted similar concerns at the NIST about the effort involved in preparing entries for Appendix C. Dr Gardner said that the goal of the proposed process was to make the system more orderly, but that problems would still arise as newer items were considered, notably in specifying the influence parameters sufficiently so that uncertainties could be properly assessed. Laboratories were encouraged to use the comments column to indicate the ability to undertake general measurements over extended ranges and to restrict claims to typical ranges and values.

The committee agreed with the process. Dr Gardner undertook to distribute the approved documents to all laboratories immediately after the CCPR meeting, and to act as the contact point for comments on the CMC items to

be included in future rounds. Dr Ikonen requested that the guidelines for entries be updated; Mr Nettleton agreed to pass this request to Dr Goodman at the NPL.

10 REPORT FROM THE WORKING GROUP ON AIR-UV SPECTRAL RADIOMETRY

Prof. Wende summarized the third report of this group to the committee (CCPR/01-05). He reminded the committee that the initial terms of reference were to study problems in the 200 nm – 400 nm range to improve conformity of measurements, adopting new techniques where available. The group had been operating for several years, had undertaken comparisons and run workshops. Advances had been made in both source-based and detector-based areas, and in reflectance and transmittance measurements. Applications had extended to wavelengths much shorter than 200 nm. Prof. Wende sought a new convenor for the group, taking this latest report and its recommendations as a basis for progress. Thanking the working group and especially Prof. Wende for their efforts, the President then called for discussion.

Prof. Sapritsky showed results obtained with newly developed black bodies using the eutectic materials Ir-C and Re-C. At 650 nm, repeatability of temperature to ~ 30 mK and spectral radiance to 0.006 % had been obtained, sufficient to monitor long-term solar changes. Mr Nettleton noted the results as impressive, that black-body techniques were again challenging detector-based radiometry, but that the lower temperatures of these new sources made UV measurement difficult. Prof. Wende remarked that the 3200 K black bodies had greatly improved air-UV radiometry, with a temperature uncertainty of 400 mK equivalent to 0.2 % (95 % confidence) in spectral emission at 300 nm. At shorter wavelengths, the lack of temperature uniformity increased uncertainties, particularly for spectral radiance.

The President noted that the working group had produced a number of detailed recommendations, and called for discussion on the future of the group. Consensus was that the recommendations (CCPR/01-5a) be accepted, and that the group be retained but renamed the Working Group on UV Radiometry (UVWG) to reflect interest at wavelengths shorter than 200 nm.

Dr Day expressed interest in excimer laser calibrations, welcoming collaboration in this area. Attention was drawn to a number of responses in the questionnaire expressing interest in applied broad-band UV measurements. Prof. Metzdorf said that the MRA has changed the way comparisons are done, and it may be better to work in smaller groups and towards more industrial needs, in a flexible manner. The President agreed that new work may be needed, but wished to continue the success of the air UV group. Prof. Wende noted that at Madrid it was decided that the group should work close to SI interests. In response to Dr Johnson he said that there are difficult requirements to be met, quoting 1 % on radiometry at 30 nm and multi-layer reflectance to 0.2 % at VUV wavelengths to meet the needs of industry. Dr Saito presented overheads showing that beam divergence was an important consideration when silicon photodetectors were used at these short wavelengths.

Consensus was that the broad-band applications should be considered separately. It was agreed that the report be accepted. Prof. Wende suggested that the new convenor should come from a laboratory other than PTB, but needed to be a delegate to the CCPR. [It was agreed that a meeting of the working group be held at the NEWRAD meeting to determine the future work programme.] It was left to those concerned to make arrangements for the meetings but there may be advantages in discussing early ideas for the work programme amongst members of the WGKC which contained most of the interested parties and which was due to meet just before the UVWG. This could help prepare the discussions and decisions in the UVWG itself. Dr Köhler agreed to circulate details to all members of the CCPR, not just the working group members, soliciting comments on the recommendations of the report. Prof. Ikonen agreed to act as convenor of the UVWG until the next meeting; there a convenor would be appointed for the subsequent period once the detailed work programme was determined. Dr Johnson said that following previous practice, an open one-day workshop on UV radiometry is planned at the NEWRAD conference. Mr Nettleton noted that the working group meeting needed to be separate and confined to the CCPR members.

11 FUTURE WORK PROGRAMME OF THE CCPR

The President noted that no new comparisons have been requested at this time for the basic quantities, but a number of responses to the questionnaire and comments during the meeting related to more industrial problems, with fibre-optic power meters and UV radiometers specifically mentioned. He asked whether there were user groups whose interests were closely related to those of the CCPR, where interaction would be of benefit preferably through CCPR sessions at existing user group meetings. Those working with display technologies or UV applications were given as examples. Dr Xu replied that he is chairman of a CIE Technical committee on UV meters. He noted that the reports of the Working Group on Air-UV Spectral Radiometry provide useful information for new laboratories, but the variation in UV meter calibrations derived more from the method of calibration rather than from any limitation set by the units, and so is not a problem for the CCPR. Dr Zwinkels said that groups such as the Council for Optical Radiation Measurement (CORM) in the United States or the Optical Radiation Club in the United Kingdom have much more input from users. Mr Nettleton said that the CCPR should listen to user concerns at related workshops, rather than run sessions, to determine problems related to better techniques or ranges different from those normally used within the CCPR. Dr Johnson quoted an exercise of this type at the NIST in radiation thermometry, where the end-users denote problems, but suppliers had proprietary interests and may not work to share solutions. Prof. Metzdorf was sceptical about input from industry. Experience with the UV thematic network had shown the difficulty of obtaining feedback. Prof. Ikonen suggested that at least one of the network working groups had useful participation from industry and that others concerned with health and safety had produced useful reports.

The President sought comment on applications in fibre optics, display technology and in measurement of appearance. Dr Day said that meetings of user groups for fibre optics were due in Cambridge (United Kingdom) in 2001 and in Boulder (United States) in 2002. Mr Nettleton said that it was necessary to clarify the CCPR and regional responsibilities, noting that EUROMET was running a supplementary comparison on fibre optic power meters. Dr Blattner asked whether the CCPR should also run such a comparison; Dr Gardner said that a previous CCPR comparison had shown good agreement on spectral responsivity at 1300 nm and 1550 nm, and that any such comparison was likely to demonstrate the variability introduced by

connectors rather than problems with the SI units. Two meetings, a topical meeting for colour imaging and the conference of the Society for Information Technology, were identified as those of user groups where problems relevant to the CCPR may be identified.

Dr Bittar asked how far the CCPR should proceed with these non-principal techniques. Mr Nettleton suggested that the RMOs may need a reference value to assist in verifying CMC claims. Prof. Ikonen said that the national metrology institutes (NMIs) can verify claims from knowledge of the method and how it is traced to the key comparison quantities. Dr Boivin agreed, suggesting that fibre-optic power meter and broad-band radiometer calibrations were not fundamental. Dr Xu said that many of the problems raised relate to standardization of geometry, couplers, etc., hence were not key comparisons and therefore not for the CCPR. Dr Bittar suggested that the more industrial issues were the concern of individual NMIs, not the CCPR. Dr Wallard agreed, but said that CCPR involvement could be determined once the issues were known. Dr van der Ham said that the CCPR questionnaire was biased towards interests of the NMIs, and that organizations such as the CIE would better represent industry. Mr Nettleton suggested that industrial issues should be a standing item on the CCPR agenda. The committee agreed and the President asked members to adopt a "listening mode" at related conferences and workshops, to identify issues that may be relevant to the CCPR. The secretary undertook to collate suggestions for new work from the questionnaires to be considered by the WGKC at its next meeting.

12 FUTURE WORK PROGRAMME OF THE BIPM

The President noted papers CCPR/01-01 and -03 dealing with this topic, and welcomed guidance for the CIPM from the CCPR. Dr Köhler commented that the BIPM had good facilities at visible wavelengths, particularly at laser wavelengths for power or responsivity measurements, but lacked both manpower and experience in other wavelength ranges. He suggested the need for a second cryogenic radiometer, monochromator-based, both as a check against cavity drift of the existing instrument and to extend scales into the UV and IR regions. The stated goal was to contribute to harmonization of

UV measurements and gain expertise that may be applicable to metrology for ozone measurements in the newly formed BIPM chemistry section, for example.

Dr Zwinkels suggested that a direct comparison of laser- and monochromator-based cryogenic radiometers might be useful. Dr Köhler replied that such information would be available in the CCPR-K2 comparison. Dr Fox reported that the NPL had found differences at the 0.01 % level only. Dr Boivin said that a monochromator-based system could produce reliable measurements at the 0.1 % level in the UV range.

Mr Nettleton observed that the existence of the MRA may have significant consequences for the BIPM, which was required to support many areas of metrology. Laboratories could now trace reliably from many sources and the BIPM may not see the same demand for calibration of artefacts; the emphasis may be shifting to the need to improve expertise and obtain more reliable uncertainty budgets. Dr Köhler replied that twelve laboratories still obtain luminous intensity and luminous flux standards from the BIPM, and that it was seen as the BIPM role to be the pilot laboratory for comparisons. Dr Johnson said that NMIs see value in being the pilot laboratory for comparisons, as it gives confidence in their measurement capabilities to their clients. The President agreed that circumstances may have changed with the introduction of the MRA, but the BIPM, at the centre of metrology, needed staff to be qualified and competent at the highest level, through undertaking research, as identified in the BIPM proposals to extend their capabilities. Dr Fox suggested that the BIPM may be better served by sending staff to other laboratories to gain expertise, for example with synchrotron techniques. Prof. Metzdorf said that the CCPR interests were defined in its key comparison quantities, and that to cover all the areas, including material properties, it may be best for the BIPM to restrict its capabilities to visible wavelengths. Dr Zwinkels disagreed, noting that problems in materials measurements lay mostly at UV and IR wavelengths. Dr van der Ham added that cavity emissivities may also be less well known outside the visible wavelength range.

Dr Wallard summarized the discussion as agreement to defer a decision on the BIPM work programme until the updating of the CIPM report on long-term needs (refer to CCPR/01-11) was completed, and until feedback is available from the CCPR attendance at workshops identifying measurement problems. He did, however, identify a consensus that the BIPM needed an active research activity that supported its overall mission. Ideally, and unless there was a good reason, it should avoid research that was already carried out

at NMIs. There was also agreement that generic research on topics such as detectors and filters and propagation of best practice was valuable. One way of dealing with "new or growth technology" areas would be to collaborate with other teams so as to develop a knowledge of the key issues. Such a mechanism would be one way of preparing the BIPM for a possible future entry into UV or IR measurements.

13 RECOMMENDATION TO THE CIPM

Dr Köhler observed that the CCPR-K3 and -K4 comparisons of luminous intensity and flux were the first in photometry where BIPM was not the pilot laboratory. The BIPM units needed to be adjusted to the key comparison reference values. Dr Stock said that the world means from the reference results were 0.30 % and 0.36 % lower for intensity and flux, respectively, than those of the 1985 comparisons which provided the bases for the BIPM disseminated units. Mr Bastie noted that the BNM has confirmed the shift in intensity in the realization of its units. Dr Köhler said that BIPM maintained the history of evolution of the realized candela, and that an article on this was being prepared for NEWRAD. He noted that the BIPM now independently realizes the photometric units based on its cryogenic radiometer, and asked whether the BIPM should disseminate its own unit or that of the key comparison reference value. Consensus was that the values should be disseminated relative to the key comparison reference values, and the recommendation P 1 to the CIPM was drafted. Mr Bastie noted that the BIPM should maintain both the 1985 and the current values internally. The independent BIPM realizations will be used to control the stability of the maintained units.

14 LIAISON TO CCT WORKING GROUP 5 ON RADIATION THERMOMETRY

Dr Johnson intimated that the former joint CCT/CCPR working group had met once since its formation in 1996, had prepared two reports, and was undertaking a small-scale comparison of filter radiometers. This pilot comparison between the NIST, the NPL, the PTB and the NMIJ was in progress with results expected in June 2001. The goal was to determine the temperature range where absolute radiometry could provide better accuracy than the International Temperature Scale of 1990 (ITS-90). Plans were in hand to circulate an imaging pyrometer. Dr Wallard noted that an outcome of this group was expected to be a "best practice" guide for temperature measurement by filter radiometry.

Mr Nettleton said that the CCPR should have connection to the new CCT working group on radiation thermometry convened by Dr Fischer (PTB), which was established last year after the CCT felt that the previous joint working group was not active. Dr Wallard replied that correspondence had already been exchanged and terms of reference for a combined group had been agreed, with Dr Fox nominated as a CCPR representative. Dr Johnson is a member of the working group as the NIST temperature representative.

15 LIAISON TO OTHER ORGANIZATIONS

15.1 CIE

Mr Bastie summarized the divisional structure of the CIE, noting six committees in Division 1 (Vision and Colour), seven in Division 2 (Measurement of Light and Radiation) and eight in Division 6 (Photobiology and Photochemistry) with interests overlapping those of the CCPR. Much of the effort in Division 6 was related to deriving action spectra. Mr Bastie noted previous CCPR recommendations on the use of SI units for these measurements and Dr Quinn asked Mr Bastie to report on future CIE developments in this area to the CCPR. Mr Bastie pointed out that previous CCPR discussions in 1977 on $V(\lambda)$ were equivalent to those now taking place

for the photobiological action spectra. It was agreed that the CCPR should produce a generic document showing the formalism to trace such spectra directly to the SI. A working group with Mr Bastie as convenor, Dr Bittar (MSL) Dr Köhler (BIPM), Dr Rastello (IEN), and representatives to be named from the NIST and the NPL was formed. Mr Bastie would inform all relevant CIE committees of the CCPR activity. The document was expected to be available for the next meeting of the CCPR.

Mr Nettleton reported that the CIE had held an uncertainty workshop, that had strong participation from industry and where the CCPR contribution was well recognized. Dr Zwinkels said that access to draft standards had been the subject of strong debate within the CIE. While wide comment was sought, the drafts were restricted as the CIE raised revenue through the sale of documents. A number of CCPR members noted their involvement with CIE committees. Prof. Metzdorf thought it would be useful if the CCPR were appraised of CIE activities in advance of CCPR meetings; Mr Bastie undertook to provide such information.

Dr Saito raised problems found with the definition of distribution temperature when considering CMC claims; Dr Köhler will raise this issue with CIE Division 2.

15.2 CORM

Dr Johnson referred members to the NIST submission for details on the CORM. Dr Wallard noted the usefulness of the CORM reports identifying measurement needs, with its 7th report due for release. Dr Boivin observed that it was common for the CIE Division 2 to hold meetings near that of the CORM as there was much common interest between the two groups.

16 OTHER BUSINESS: NEWRAD

Dr Johnson gave details of plans for the four-day NEWRAD meeting, with a workshop on UV measurements to be run by the Working Group on UV Radiometry, planned for the fifth day. Papers lodged at the meeting will be considered for a topical issue of *Metrologia*, as in previous conferences. A general discussion took place about timely publication of conference

proceedings and obtaining external professional editing services. Mr Nettleton suggested that a best paper and poster award be given. A panel discussion, “Radiometry from space” was planned during the conference.

17 NEXT MEETING

The next meeting was set for the period April – May 2003. Dr Gardner noted that he will be retired prior to that meeting and wished the committee well in its future work. The President thanked him for his contributions to the CCPR and declared the meeting closed.

J.L. Gardner, Rapporteur

May 2001

revised October 2001

RECOMMENDATION OF THE CONSULTATIVE COMMITTEE FOR PHOTOMETRY AND RADIOMETRY SUBMITTED TO THE INTERNATIONAL COMMITTEE FOR WEIGHTS AND MEASURES

RECOMMENDATION P 1 (2001): Photometric standards of the International Bureau of Weights and Measures (BIPM)

The Consultative Committee for Photometry and Radiometry,

considering that

- it pertains to the BIPM to disseminate the best possible realizations of the SI units;
- the values attributed to the standards of luminous intensity and luminous flux maintained by the BIPM should both promote worldwide uniformity and be consistent with the 1979 definition of the candela;
- the Mutual Recognition Arrangement (MRA) implies that the realizations maintained and disseminated by the BIPM be recognized worldwide;
- the means of the results of the key comparisons of the national realizations of the candela and the lumen, CCPR-K3.a and CCPR-K4 (both approved following the 15th meeting of the CCPR in 1999), represent the most reliable reference values;
- the BIPM has already in the past maintained as references for the photometric units sets of standards the values of which were established from the results of international comparisons;
- the value of luminous intensity attributed to the standards maintained by the BIPM since 1985 is 0.30 % greater than the key comparison reference value of CCPR-K3.a;
- the value of luminous flux attributed to the standards maintained by the BIPM since 1985 is 0.36 % greater than the key comparison reference value of CCPR-K4;

recommends that

- the BIPM continue, as in the past, to maintain and disseminate realizations of the photometric units of the SI representing the means deduced from comparisons;
- the values attributed to the standards maintained by the BIPM as representing the candela and the lumen be reduced, with effect from 1st January 2002, by 0.30 % and 0.36 % respectively, so as to conserve and disseminate the reference values of the relevant key comparisons;
- these adjustments be published.

APPENDIX P 1.
Working documents submitted to the CCPR at its 16th meeting

(see the list of documents on page 51)

LIST OF ACRONYMS USED IN THE PRESENT VOLUME

1 Acronyms for laboratories, committees and conferences

APMP	Asia/Pacific Metrology Programme
BIPM	International Bureau of Weights and Measures/Bureau International des Poids et Mesures
BNM-INM	Bureau National de Métrologie, Institut National de Métrologie, Paris (France)
CC	Consultative Committee of the CIPM
CCPR	Consultative Committee for Photometry and Radiometry/ Comité Consultatif de Photométrie et Radiométrie
CCT	Consultative Committee for Thermometry/Comité Consultatif de Thermométrie
CENAM	Centro Nacional de Metrologia, Mexico (Mexico)
CGPM	General Conference on Weights and Measures/Conférence Générale des Poids et Mesures
CIPM	International Committee for Weights and Measures/Comité International des Poids et Mesures
CORM	Council for Optical Radiation Measurements (United States)
CSIR-NML	Council for Scientific and Industrial Research, National Metrology Laboratory, Pretoria (South Africa)
CSIRO*	see NML-CSIRO
ETH	Eidgenössische Technische Hochschule/Swiss Federal Institute of Technology, Zurich (Switzerland)
ETL*	Electrotechnical Laboratory, Tsukuba (Japan), see NMIJ/AIST
EUROMET	European Collaboration on Measurement Standards
HUT	Helsinki University of Technology, Helsinki (Finland)
IEC	International Commission on Illumination/Commission Internationale de l'Éclairage
IEN	Istituto Elettrotecnico Nazionale Galileo Ferraris, Turin (Italy)

* Laboratories marked with an asteristisk either no longer exist or operate under a different acronym.

IFA-CSIC	Instituto de Física Aplicada, Consejo Superior de Investigaciones Cientificas, Madrid (Spain)
INM*	Institut National de Métrologie, Paris (France), see BNM
INTI	Instituto Nacional de Tecnología Industrial, Buenos Aires (Argentina)
ISO	International Organization for Standardization
JCRB	Joint Committee of the Regional Metrology Organizations and the BIPM
KRISS	Korea Research Institute of Standards and Science, Daejeon (Rep. of Korea)
METAS	(formerly the OFMET) Swiss Federal Office of Metrology and Accreditation, Wabern (Switzerland)
MRA	Mutual Recognition Arrangement
MSL	Measurement Standards Laboratory of New Zealand, Lower-Hutt (New Zealand)
NEWRAD	Conference on New Developments and Applications in Optical Radiometry
NIM	National Institute of Metrology, Beijing (China)
NIST	National Institute of Standards and Technology, Gaithersburg (United States)
NMI	National Metrology Institute
NMi VSL	NMi Van Swinden Laboratory, Nederlands Meetinstituut, Delft (The Netherlands)
NMIJ/AIST	National Metrology Institute of Japan, National Institute of Advanced Industrial Science and Technology, Tsukuba (Japan)
NML-CSIRO	National Measurement Laboratory, CSIRO, Lindfield (Australia)
NPL	National Physical Laboratory, Teddington (United Kingdom)
NPLI	National Physical Laboratory of India, New Delhi (India)
NRC	National Research Council of Canada, Ottawa (Canada)
NRLM*	National Research Laboratory of Metrology, Tsukuba (Japan), see NMIJ/AIST
OFMET*	Office Fédéral de Métrologie/Eidgenössisches Amt für Messwesen, Wabern (Switzerland), see METAS
OMH	Országos Mérésugyi Hivatal, Budapest (Hungary)
PMOD/WRC	Physikalisch-Meteorologisches Observatorium Davos, World Radiation Center, Davos (Switzerland)

PSB	Singapore Productivity and Standards Board (Singapore)
PTB	Physikalisch-Technische Bundesanstalt, Braunschweig and Berlin (Germany)
RMO	Regional Metrology Organization
SADCMET	SADC Cooperation in Measurement Traceability
SIM	Sistema Interamericano de Metrologia
SMU	Slovenský Metrologický Ústav/Slovak Institute of Metrology, Bratislava (Slovakia)
TempMeko	International Symposium on Temperature and Thermal Measurements in Industry and Science
UME	Ulusal Metroloji Enstitüsü/National Metrology Institute, Marmara Research Centre, Gebze-Kocaeli (Turkey)
UVWG	Working Group on UV Radiometry
VNIIOFI	Institute for Optophysical Measurements, Gosstandart of Russia, Moscow (Russian Fed.)
WGKC	Working Group on Key Comparisons
WMO	World Meteorological Organization

2 Acronyms for scientific terms

CCD	Charge-coupled-device camera
CMC	Calibration and Measurement Capabilities
FEL	Type of lamp supplied by General Electric Co. (United States)
IR	Infrared
FT-IR	Fourier transform, infrared region
ITS-90	International Temperature Scale of 1990
LED	Light-emitting diode
SI	International System of Units/Système International d'Unités
UV	Ultraviolet